Chapter 7
Industrial Revolution

Between 1780 and 1850, in a space of just seven decades, the face of England was changed by a far-reaching revolution, without precedent in the history of mankind.

Glasgow University had one of the Newcomen engines for its natural philosophy class. In 1763, one hundred years after the birth of Newcomen, this apparatus went out of order and Professor John Anderson gave James Watt (1736–1819) the opportunity to repair it. After the repair and while experimenting with it, Watt was struck by the enormous consumption of steam because, at every stroke, the cylinder and piston had to be heated to the temperature of boiling water and cooled again. This prevented the apparatus from making, with the available boiler capacity, more than a few strokes every minute. He quickly realized that wastage of steam was inherent in the design of the engine and became obsessed with the idea of finding some remedy. From the discovery of Joseph Black (1728–1799), he deduced that the loss of latent heat was the most serious defect in the Newcomen engine [2]. The work of James Watt [3] is thus the key application of science to engineering which led to the birth of the industrial revolution.

In 1765 he conceived the idea of a separate condensing chamber for the steam engine to separate the condensation system from the cylinder, injecting the cooling water spray in a second cylinder, connected to the main one [1]. When the piston had reached the top of the cylinder, the inlet valve was closed and the valve controlling the passage to the condenser was opened. External atmospheric pressure would then push the piston towards the condenser. Thus the condenser could be kept cold and under less than atmospheric pressure, while the cylinder remained hot. Important as the separate condenser idea was, in the fully developed version of 1775 that went into production, changes had to be more far-reaching. There was no spray, the condenser being immersed in a water tank and at each stroke the warm condensate was drawn off and sent up to a hot well by a vacuum pump which also helped to evacuate the steam from under the power cylinder. The still-warm condensate was recycled as feed water for the boiler.

James Watt's single-acting pumping engine of 1788 is shown in Figure 7.1. This engine worked a crossbeam for pumping. The cylinder was closed (by a cap) and heated by a warm steam jacket. The condenser, positioned underground, was cooled

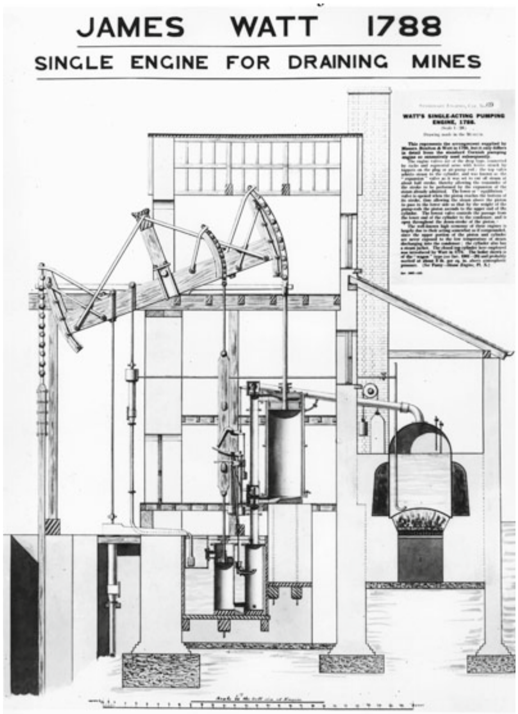

Fig. 7.1 James Watt's Steam Engines in 1788 - Pumping Engine. (Courtesy National Museum of Science & Industry)

and vacuum operated (by a pump). When the piston reached the top of its stroke the exhaust-valve opened and a partial vacuum was produced below the piston (inside the cylinder communicating to the condenser). Above the piston, at the same time, the entrance of steam helped the atmospheric pressure to drive the piston down. On this stroke the crossbeam raised water in the pump. When the piston reached the bottom of the stroke the inlet valve closed and an equilibrium valve opened to allow steam to pass from above to below the piston. The engine piston (now with the same pressure above and below) was driven up by the crossbeam and the descent of the very, very heavy pump piston and rod. Note the presence of the condenser and the warm steam jacket that surrounds the cylinder.

There was a heavy demand for an engine that could produce a rotary motion to drive factory machinery. The reciprocating engine that produced rotary motion revolutionalized the world; the first engine James Watt built in 1787–1788 is also shown in Figure 7.2. Reciprocating machinery has inherent disadvantages at high speeds, they have practically disappeared in the modern day world; there are still steam locomotives operating in a few places, e.g., Fairy Queen, the oldest running vintage steam locomotive in the world, built in the year 1855 by the British firm Kinston, Thompson & Hewitson for the British firm East India Railways, see Figure 7.3, and

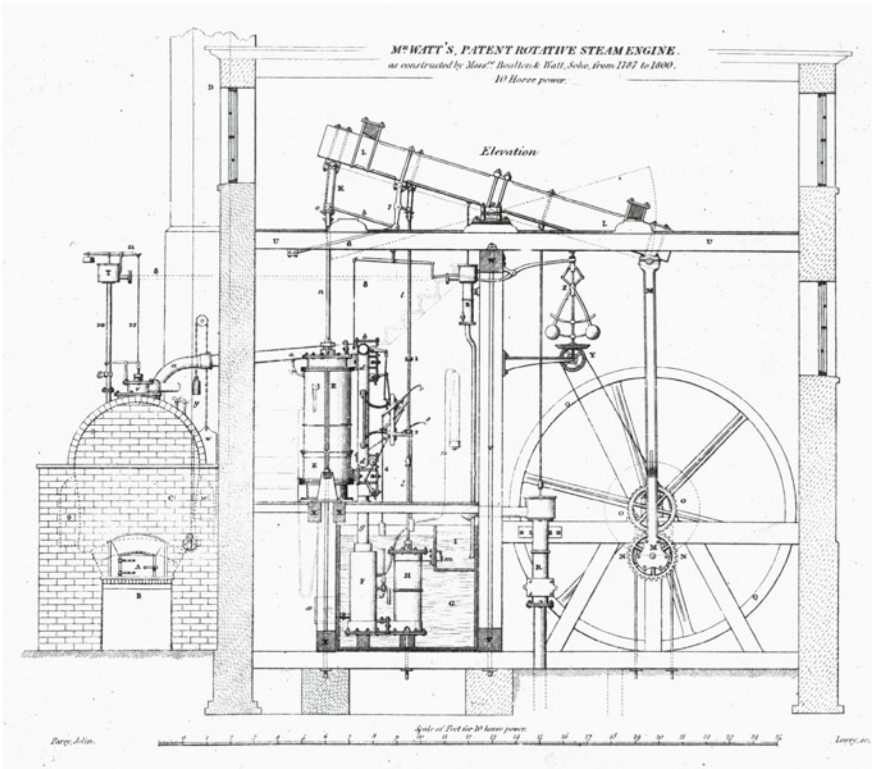

Fig. 7.2 James Watt's Steam Engines in 1788 – Engine with rotary motion for factories. (Courtesy National Museum of Science & Industry)

Fig. 7.3 Fairy Queen (http://www.visit-indya.com/tours/fairyqueen.html)

occasional reciprocating engines for producing small amounts of power in sugar mills, but they are gone. Internal combustion engines still thrive for transportation, power generation, and so on.

The internal combustion engines could run at higher speeds with a multi cylinder arrangement and reciprocating parts balancing. However, they are not vibration free engines. Though reciprocating machines are fascinating, they have no rotors directly and in the drive train too, the speeds are limited because of the reciprocating drive. Thus, not much attention was given to rotor dynamics during this era. We will study the growth of turbomachinery which necessitated the studies on rotor dynamics.

References

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2. Ogg, David (1965) *Europe of the Ancient Regime: 1715–1783*. Harper & Row.
3. Rao, J.S. (1999) Watt – Two Hundred Years After His Retirement, in *10th World Congress on the Theory of Machines and Mechanisms*, Oulu, Finland, Vol. 1, p. 63.